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ASTRONOMY AND ASTRONOMERS IN THEIR RELATIONS TO THE PUBLIC.

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At this meeting of this Society, it is the custom for the retiring President to address you on some scientific subject, and it has occurred to me that it might be well to consider here "Astronomy and Astronomers in Their Relations to the Public," and in doing so attempt to answer some of the questions that an intelligent public frequently asks, and at the same time indicate some of the services to both that have been rendered by astronomical societies.

The work of the astronomer, like that of other scientists, is only a little understood by the general public. Nevertheless, the relations between the two are always the most cordial; and while the astronomer may often be questioned as to the utility of his labors, he can never complain of lack of appreciation. On the contrary, the interest that attaches to a working observatory, especially one that is readily accessible, is always so great that regulations governing the admittance of visitors are indispensable, in order that any time may be reserved for scientific work.

As a result of this interest, great advantages accrue to the science. It has given the world many of its great observatories, those of the University of Chicago and of the University of California standing pre-eminent in the power of their telescopes. So great, indeed, has become the generosity of those who are not astronomers, that it would almost seem that astronomers have only to ask for instruments and observatories to find appreciative persons ready to supply their needs. This responsiveness is all the more remarkable when we consider that the results of the astronomer's labor are, in general, far removed from commodities having a commercial value. New comets, new planets, new satellites, new stars, worlds, and systems of worlds may be discovered, and their histories may be long and interesting, but not one of them can be exchanged for real or personal property.

From what has been said, it must not be understood that astronomy has no practical applications. Far from that. The determination of time, of latitude, of longitude, of azimuth, are all problems of practical astronomy, and they are among those that have more or less important relations to the ordinary affairs of life.

The land is crossed in every direction by roads of steel. Smooth tracks, swift locomotives, and comfortable cars make travel easy and enjoyable; strong and commodious cars make it possible for cities widely separated to carry on gigantic commercial transactions. The trains glide along the tracks with great speed, and are ever meeting and passing each other. This they do with such precision that accidents are comparatively few — so few, in fact, that on the average, only one passenger out of a million and a half loses his life. This precision is due, in part, to their being controlled by some central clock. But who controls that clock? Who, with entire confidence that his statements are true, can say that the time it indicates is correct or not? Astronomers, by their long and laborious investigations, based on a multitude of refined observations, have learned the motions of the heavenly bodies with such accuracy that they can predict the positions these bodies will occupy in the sky for many years to come. They have prepared tables of these motions, giving the positions of the Sun, Moon, planets, and principal stars for given epochs. By means of these tables and astronomical observation, they can, among other things, accurately determine the time, and in no other way can it be done.

It was many years ago that the engineer applied mathematics to the pressure of the wind and pressure of the wave, and balanced the one against the other. The sail caught the wind, the hull pressed the wave, and the famous clipper ships with their precious cargoes sprang forward ten thousand miles, making records of long-distance speed that have seldom been equaled. By day and by night, the Sun, Moon, and stars, the compass, their charts, and well-rated chronometers were their faithful guides, directing their courses across the trackless oceans. The ships found their ways, and captains delivered rich cargoes, bringing handsome returns for their voyages. Without these guides, such voyages could not have been made, and if they had not been made, the loss to commerce and civilization would have been incalculable.

The circumstances that hastened, if they did not occasion the establishment of the Royal Observatory at Greenwich, in 1675, are full of interest, and since they refer to one of the most important practical applications of astronomy, I will give a brief account of them.

At this time, a Frenchman, calling himself LE SIEUR DE PIERRE, came to the English court and announced the discovery of a method of finding the longitude of a place. Incited by the discovery of America and of routes by sea to India, the British ships were beginning to find their way to all parts of the world. Colonies were planted in many lands, and a commerce built up that has added vastly to the material wealth of England. On these long voyages, methods of finding latitude and longitude were of prime importance. It was easy enough to find latitude, but how to find longitude was a pressing problem for nearly a century after the time of which we speak.

A commission composed of distinguished men, with the privilege of adding others to their number if they saw fit, was selected to hear and consider the method proposed by LE SIEUR, and to report the results of their inquiries to the king. Among those whom the commissioners invited to join their number was JOHN FLAMSTEAD, then somewhat under thirty years of age, but with a considerable reputation because of his astronomical observations.

LE SIEUR'S method depended on the Moon's motion, and required as data the date of observation, the latitude of the place, the Moon's altitude, and the altitude of two known stars. FLAMSTEAD at once pointed out that the method was impracticable, and in the controversy that followed he wrote two letters, one to LE SIEUR and one to the commissioners. In these letters he said: "If we had astronomical tables that would give us the two places of the fixed stars and the Moon's true places, both in longitude and latitude, nearer than half a minute, we might hope to find the longitude of places by lunar observations. But that we were so far from having the places of the fixed stars true, that the Tychonic catalogues often erred ten minutes or more; * * *

and that the best lunar tables differ one quarter, if not one third, of a degree from the heavens."*

FLAMSTEAD'S letter to the commissioners was shown to King Charles. He was startled at the assertion of the fixed stars' places being false in the catalogue, and with much vehemence said: "I must have them anew observed, examined, and corrected, for the use of my seamen. I must have it done." And on being asked who could or should do it, the king replied: "The person who informs you of them."

Accordingly, on March 4, 1674–5, the king signed a warrant for FLAMSTEAD'S salary, a portion of which reads as follows:—

"Whereas, we have appointed our trusty and well-beloved JOHN FLAMSTEAD, Master of Arts, our astronomical observator, forthwith to apply himself with the most exact care and diligence to rectifying the tables of the motions of the heavens, and the places of the fixed stars, so as to find out the so much-desired longitude of places for the perfecting the art of navigation." The rest of the warrant relates to the payment of his salary, which was £100 a year.

On June 22, 1675, King Charles signed the warrant for building the observatory. It begins as follows:—

"Whereas, in order to the finding out of the longitude of places for perfecting navigation and astronomy, we have resolved to build a small observatory within our park at Greenwich, upon the highest ground, at or near the place where the castle stood, with lodging-rooms for our astronomical observator and assistant."

The foundation of the observatory was laid August 10, 1675. No provision was made for instruments. FLAMSTEAD had to provide them himself, and at his death, after forty-four years of laborious service, they "were actually claimed by the government as their own, and his executors were annoyed with a vexatious and troublesome lawsuit on that account." [BAILY: *An Account of FLAMSTEAD*, p. 30.]

The Royal Observatory at Greenwich, founded under the circumstances as related, and having especially in view the kinds of astronomical work that lead to results of practical value, has continued to the present time regularly to make those observations needed for "rectifying the tables of the motions of the heavens." It is impossible to give, or even to form, an adequate

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*FLAMSTEAD'S History of his own Life in BAILY'S *Account of the Rev. John Flamstead*, page 38.

idea of the great importance of the astronomical work that has been done at Greenwich.

The long series of observations, on the principal bodies of the solar system and the brighter fixed stars, surpassing in duration and magnitude any programme of work that could reasonably be expected from any, except national observatories, is one of the richest possessions of astronomy. It has furnished the data for many of the most important investigations relating to the motions of the heavenly bodies; the determination of these motions being the principal problem that astronomers in all ages have been attempting to solve. Indeed, this problem constituted so large a part of astronomy even at the end of the first third of this century, that BESSEL, the greatest of practical astronomers, wrote as follows:—

"What astronomy is expected to accomplish, is evidently at all times the same. It must lay down rules by which the movements of the celestial bodies, as they appear to us upon the Earth, can be computed. All else which we may learn respecting these bodies, as for example, their appearance and the character of their surfaces, is, indeed, not undeserving of attention, but possesses no proper astronomical interest. Whether the mountains of the Moon are arranged in this way, or in that, is no further a subject of interest to astronomers than is a knowledge of the mountains of the Earth to others. Whether *Jupiter* appears with dark stripes upon its surface, or is uniformly illuminated, pertains as little to the inquiries of the astronomer; and its four moons are interesting to him only for the motions they have. To learn so perfectly the motions of the celestial bodies, that for any specified time an accurate computation of them can be given — that was, and is, the problem which astronomy has to solve. NEWTON gave it no new problem; but his discovery encouraged the hope that a complete solution to the old one could be obtained. This before his time was not deemed possible."

Astronomy has advanced a long way since these words by BESSEL were written. Two generations of theoretical and practical astronomers have lived since then; the former have labored to perfect the analysis relating to the motions of the heavenly bodies, and to test its accuracy by comparing observed and computed places, and the latter, following the methods of which BESSEL was the great exponent, have developed the theory of their instruments and the theory of observation with mathematical rigor, and have neglected only those terms which could be shown to be insensible in their effects. Astronomy has also advanced with marvelous rapidity in other directions. The investigations which BESSEL characterized as not undeserving of attention, but as possessing no proper astronomical interest, together with those that have arisen through the development of spectroscopy, have unexpectedly attained such importance, and are so full of promise for the future, as to merit a co-ordinate place beside the investigations of the older astronomy, and constituting, as they do, a new science, to be distinguished by an independent name—astrophysics.

The older astronomy has lost none of its importance. There has been no halt in its progress, and no diminution in the interest that attaches to its results. This will always be the case. For so long as civilization endures, it will be a factor in the affairs of men. Besides, there are moral reasons. In common with other scientists, the astronomer must strive to a perfect understanding of the action of natural and moral forces; he cannot stop where immediate practical applications end. His researches are based on far-reaching principles, and lead to results that unfold prospects among the greatest and sublimest furnished by any department of human knowledge, and which, through the awakening and proper use of the imagination, may be classed among the most potent of moral and spiritual forces.

The investigations of the older astronomy are, from an astronomical standpoint, characterized by a singleness of purpose. Postulating the law of gravitation and the principles of rational mechanics, it seeks to determine the motions of the heavenly bodies. The newer astronomy is likewise characterized by a singleness of purpose. Calling to its aid every available means of inquiry, it endeavors to ascertain the nature and conditions of these bodies, and thence to learn what has been their past and what will probably be their future histories. Half a century ago, it seemed that the future advancement of astronomy would be along the lines already marked out, and that it would consist chiefly in perfecting the science by increasing the precision of its results. It did not then seem probable that new departments of astronomy would arise, and some of the results already obtained through astrophysical research would then have appeared, even to the boldest imagination, as hopelessly beyond human possibility. The spectroscopic and other new methods of investigation have appeared, more and more powerful telescopes have been constructed, by the new methods and by the increase of power many old problems have been solved, but new problems in greater numbers have arisen to take their places. It will always be so. The universe is infinitely varied. A few astronomers in a few short years can at best fathom only a comparatively small number of its mysteries.

Nearly three centuries have elapsed since the invention of the telescope, and during this entire period rapid and wonderful improvements have marked its history. For more than two hundred years the popular use of the telescope was almost entirely unknown. In fact, it was not until near the middle of the present century, when the Cincinnati Observatory was established, that the great revolution in this respect was begun. The foundation of this observatory also marks an epoch in the history of science in this country.

In 1832, AIRY, "the Astronomer Royal of England, in his celebrated 'Report on Astronomy' before the British Association, after recounting with high eulogium what had been accomplished in the building of astronomical observatories throughout the old world, closes by saying, that as for the United States he did not know of the existence of a single public observatory within the limits of the entire country." It was then the general opinion abroad that the nature of our institutions was not favorable to the development of pure science. It was only ten years later, however, that the Cincinnati Astronomical Society subscribed $9500 for the purchase of an instrument, and made a provisional contract for what was then the second largest refracting telescope in the world. Since then, our observatories have rapidly increased in number, and have become no less famous for the character of their work than for the power and excellence of their telescopes.

The history of the foundation of the Cincinnati Observatory is very interesting. By a series of popular lectures, General MITCHEL, then a Professor at Cincinnati, awakened deep interest in the science of astronomy. The Cincinnati Astronomical Society was the immediate result, and thence came the Cincinnati Observatory, with its long and honorable career.

On the 9th of November, 1843, the corner stone of the observatory was laid by JOHN QUINCY ADAMS, in the presence of a vast multitude, with appropriate ceremonies, and followed by the delivery of an address replete with beauty and eloquence. It was the intention of the board of directors to pay for their telescope before proceeding to the erection of the building. At this time only $3000 had been paid in, and to meet their engagements, $6500 would have to be collected by the following June, when it was expected the great telescope would be ready for shipment to the United States. General MITCHEL became the general agent of the society, and by undeviating perseverance raised the entire sum before the specified time had expired. But after paying for the instrument, not one dollar in cash remained with which to begin the construction of the observatory building, which, at the lowest estimate, must cost five or six thousand dollars. Some two or three thousand dollars had been subscribed, payable in work and materials; a suitable site on the summit of Mt. Adams had been given, subject to certain conditions; but no one could be found who would take the contract for the building in the face of the many contingencies by which the affairs of the society were surrounded. General MITCHEL determined to hire workmen by the day, and personally to superintend the erection of the building. In attempting to contract for the delivery of brick on the summit of Mt. Adams, he was asked such a high price for the hauling, on account of the steepness of the hill, that all idea of a brick building was at once abandoned, and it was decided to build of limestone, an abundant supply of which could be had on the grounds of the society by quarrying. The exorbitant charges made for delivering lime were at once disposed of by building a limekiln on the grounds. In a few days it was completed, filled, and on fire, and soon lime in abundance was ready. Sand was the next item for which extravagant charges were made. With considerable difficulty, permission was obtained to open a sandpit not far away, which had long been closed for fear that further excavation would endanger a house on the hill above it. Then the price asked for hauling the sand was so great that General MITCHEL was forced to buy horses, and in not a few cases to fill the carts with his own hands and drive them to the top of the hill, in order to demonstrate practically how many loads could be fairly made in a day. The nearest water was at the foot of the hill, half a mile away. To avoid hauling so far, a dam was thrown across one of the deepest ravines on the hilltop, and the rains allowed to fill it, to furnish the water needed for mixing the mortar.

The work of construction began early in June, 1844. The force of hands for the first week consisted of two masons and one man to tend them. With this force it would have taken about twenty years to have erected the building, yet according to the bond it must be completed by the following June, or the title to the site must be forfeited.

By the end of the first week, General MITCHEL had raised enough money to pay his hands. He instructed his foreman to double his force for the next week. At the end of it, he had again obtained sufficient money to pay them in full. The force was increased week after week in the same manner, until not less than fifty day laborers were actually engaged in the erection of the Cincinnati Observatory, and as many more in the shops in the city were paying their subscriptions by work for the different parts of the building. The doors were being made by one carpenter, the window frames by another, the sashes by a third, a painter took them from the joiner, and in turn delivered them to the glazier, and finally a carpenter paid his subscription by hanging them, using locks, hinges, cords, pulleys, and weights, all obtained by subscription.

Each Saturday night saw the funds exhausted; each new week was commenced in the full confidence that industry and perseverance would work out its legitimate results. To raise the cash means was the greatest difficulty. Frequently, four or five trades had to be made to convert due bills into cash, and not infrequently did individuals cash their own due bills at a discount.

In July and August, the work went on rapidly, and in September, General MITCHEL had the great satisfaction of seeing the building up and covered, without having incurred one dollar of debt and without neglecting his duties as Professor of Mathematics and Philosophy in the Cincinnati College, where he was teaching five hours a day.

By the terms of the subscription, each contributor, whether of cash, work, or material, became a member of the Cincinnati Astronomical Society, and came to have a personal interest for himself and for his family, in this important observatory and its great telescope. There were about 800 contributors, from all professions and all ranks of society; probably not less than 4000 persons had acquired the right to look at the heavenly bodies through this, the then second largest refractor in the world. At first, many nights were devoted to their instruction and entertainment; for the first year, only one night each week was reserved for scientific work, and in the second year, only three nights each week.

We have now noted, briefly, the circumstances attending the founding of two important public observatories,—one by royal favor, the other by the will of the people. Both have long and honorable careers; both have served as examples leading to the establishment of other observatories, and both have ministered to the wants of the people, though in very different capacities.

A little more than three quarters of a century ago the Astronomical Society of London was organized, and the objects of the original members are stated in an address circulated before their first public meeting, in the following words:—

"To encourage and promote their peculiar science by every means in their power, but especially by collecting, reducing, and publishing useful observations and tables; by setting on foot a minute and systematic examination of the heavens; by encouraging a general spirit of inquiry in practical astronomy; by establishing communication with foreign observers; by circulating notices of all remarkable phenomena about to happen, and of discoveries as they arise; by comparing the merits of different artists eminent in the construction of astronomical instruments; by proposing prizes for the improvement of particular departments, and bestowing medals or rewards on successful research in all; and finally, by acting, as far as possible, in concert with every institution, both in England and abroad, whose objects have anything in common with their own, but avoiding all interference with the objects and interests of established scientific bodies."

Surely, this was an ambitious program of work for a new society, and that it was able to carry it out in full measure demonstrates that its council contained masterly ability, and that its affairs were wisely and carefully administered. Its success from the beginning was far beyond expectation. In its first list of members and associates, we find many distinguished names. BABBAGE, BREWSTER, FARADAY, HERSCHEL, ARAGO, BESSEL, GAUSS, LAPLACE, OLBERS, PIAZZI, and STRUVE are among the number. The funds of the society grew, and were carefully invested. Even at the "first annual general meeting" the council was able to report that the invested funds amounted to more than $3700. Presents of books, papers, and instruments have been continually received for more than seventy-five years, so that at the present time the property, aside from investments, is so extensive that insurance to the extent of £5500, or, approximately, $27,500, is no longer regarded as sufficient. Its library has always been accessible at all reasonable hours, and a generous spirit has prevailed in regard to its instruments. In its very infancy it began the publication of its *Memoirs*, those substantial astronomical papers intended for the advancement of science, which, in the aggregate, now number more than 15,000 quarto pages. Just seventy years ago it added to its publications the *Monthly Notices*, which are now in their fifty-seventh volume.

The society soon became, and still continues to be, a great force in the astronomical world. The great value of its publications, the interest in its regular monthly meetings, the advantages arising from its library and many other privileges have combined to make it popular at home and abroad. It has aided in the advancement of science in a purely technical way; and again by bringing science and the people closer together, to the great benefit of both.

The society's early success was attributed by its members themselves to the policy adopted in the beginning, "by acting in concert with every institution, both in England and abroad, whose objects have anything in common with its own; but avoiding all interference with the objects and interests of established scientific bodies." To this may be added the active and sincere co-operation of its ablest members, without which the healthy growth and prosperity of a scientific society is impossible, and which can only exist when, in the management, there is entire freedom from direction such as wielded by the typical political boss.

The Astronomical Society of the Pacific has been in existence about eight years. Its energies have been devoted to the diffusion of astronomical knowledge by means of popular lectures and by its *Publications*. In this way its services have been valuable to the public and to astronomers. The welfare of the Society demands that work along these lines shall be continued, and that it shall be made as good in quality as can be obtained, and as large in quantity as is consistent with an economical management. An increase in the membership of the Society is eminently desirable, for this would mean an increase of its funds, of its possibilities, and of its responsibilities. The limits of its usefulness will not be reached until it becomes an active force, stimulating and encouraging astronomical research in all its departments, and spreading astronomical knowledge to all classes.

San Francisco should have a great astronomical library. Nothing could be more appropriate than that this should be the property of the Astronomical Society. A beginning in this direction has already been made. There are now some funds for library purposes, there should be more; and from time to time, valuable books and papers are being received from corresponding institutions and from individuals. Every gift in this way is welcomed; all works on astronomy and the related sciences have a value in such a place.

Since the Society is very largely composed of those who are not professional astronomers, it may be said that the library need contain only popular works. But this is plainly not enough. It should be technical as well as popular, and as soon as may be, complete in the periodical literature of the science. During the past year, in connection with my Presidency of the Society, I have learned of more than one case of young persons of this city who are interested in the science, not as amateurs, but with the expectation of becoming professional astronomers. To these the Society has a duty, that of providing library facilities commensurate with their aims. Such persons, if of marked ability, soon largely outgrow popular books, and demand the works of the masters and the entire range of periodical literature to satisfy their wants.